SEEDLING DEATH OF *DESMODIUM INTORTUM* IN THE QUEENSLAND WALLUM WITH SPECIAL REFERENCE TO POTASSIUM CHLORIDE FERTILIZER

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ABSTRACT

Three field experiments studied seedling mortality of Desmodium intortum *cv. Greenleaf at Beerwah, south-east Queensland. The results suggested that* D. intortum *seedlings were susceptible to chloride levels in the broadcast basal fertilizer applied to the infertile Beerwah soil. KCl rates associated with seedling death were from approximately* 100 *to* 200 *kg KCl/ha.*

Seedling death usually occurred two to six weeks after emergence and was accompanied by a reduction in yield of surviving plants. The harmful effects of potassium chloride varied markedly between different sowings, probably associated with the effect of pre and post sowing weather conditions on chloride movement and uptake. Chloride levels of below 1% *in surviving eight week old plants were very rarely associated with previous seedling death, whereas levels of above* 2% *were usually associated with seedling death.*

It is suggested that the risk of chloride toxicity could be reduced by using either less potassium chloride at sowing, or else potassium sulphate.

INTRODUCTION

The impetus for studies described in this paper came from an experiment (Jones 1970) in which the establishment of three pastures species, *Setaria sphacelata* (C.P.I. 33453), *Macroptilium atropurpurem* (cv. Siratro) and *Desmodium intortum* (cv. Greenleaf) was examined in both a fertile prairie soil at Samford and an infertile low humic gley at Beerwah, south-east Queensland. Approximately 75% of emerged desmodium seedlings died at Beerwah whereas there was negligible death of other species at Beerwah or of any species at Samford.

Three experiments studying possible reasons for this death were sown in summer of 1969/70 and 1970/71 at sites adjacent to the initial experiment.

METHODS AND RESULTS

Experiment 1—Methods

This concentrated on factors possibly connected with nodulation and soil antibiotic effects on sandy soil newly cleared of vegetation (Cass-Smith and Holland 1958, Holland 1962). As dieldrin was used as a seed dressing in the initial study it was included as a variable in this experiment.

The Samford site, previously a white clover/paspalum pasture, had received some 2,500 kg of superphosphate/ha and 1,000 kg of KCl/ha over the previous eight years, of which 250 kg of superphosphate and 100 kg of KCl were applied six months previously.

The Beerwah site was newly cleared virgin wallum. Fertilizer, applied by hand and raked in over the top 4 cm of soil immediately before sowing into moist soil, comprised 800 kg lime/ha and 800 kg/ha of a fertilizer mixture comprising 8.3% available phosphorus, 8.3% K as KCl and trace elements.

Factorial combinations of the following treatments were applied to 2 m long rows of Greenleaf desmodium sown with 600 viable seeds.

(1) Soil sterilant—nil and Vapam (32.7% sodium methyl dithiocarbamate) at 0.74 litres/10 sq. m one month before sowing.

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(2) Dieldrin—nil and as seed dressing at 2 g active ingredient/kg seed.
(3) Nitrogen—nil and 0.6 g of N as NH_4NO_3 3 cm beneath the 2 m row.
(4) Inoculum level—usual peat inoculation and excess peat applied with seed at 2 g of peat per 2 m row.
(5) Times of sowing—two sowings, two weeks apart.

Rows were seeded into a good seedbed with two replicates of each treatment, a total of 128 rows. Blocks containing eight rows of the dieldrin × nitrogen × inoculum treatments were subjected to the sterilant × time of sowing treatments. The Beerwah experiment was sown on the day after the Samford experiment and all subsequent measurements made similarly.

Measurements were made as follows:

1. Seedling emergence and death over an eight weeks period from sowing.
2. Yield of row top growth at eight weeks after sowing.
3. Chemical analysis of top growth.
4. Half of each row, chosen at random, was dug up after eight weeks and 50 plants rated for nodulation.

Experiment 1—Results

Rainfall was good at both sites and there was no indication that growth was limited by moisture stress.

No treatments affected emergence, which was better at Samford than Beerwah (Table 1). There was no effect of sterilant, dieldrin, nitrogen or inoculum level at the Samford site where there was no seedling death and growth was very good, though slower in the second sowing. Almost all Samford plants were nodulated although nodules were small (Table 1).

TABLE 1

Characteristics of D. intortum *seedling growth at two sites—experiment* 1

	Samford		Beerwah	
	1st Sowing	*2nd Sowing*	*1st Sowing*	*2nd Sowing*
Emergence (% of viable seed)	69.8 ± 2.2	73.0 ± 2.2	49.6 ± 1.9	45.5 ± 3.5
Survival (seedling numbers at 8 weeks as % of number at two weeks)	101.9 ± 0.8	96.9 ± 1.0	67.8 ± 3.9	43.8 ± 4.8
Row D.M. yield (g/2 m row)	75.9 ± 1.5	48.7 ± 1.2	29.0 ± 1.9	11.1 ± 1.6
% plants without nodules	1.4 ± 0.3	4.2 ± 0.7	21.5 ± 5.1	35.7 ± 5.8
% plants with all nodules < 2 mm	97.2 ± 0.4	95.7 ± 0.7	23.8 ± 2.1	33.0 ± 3.6
% plants with largest nodule 2–3 mm	1.4 ± 0.4	0.1	43.4 ± 3.6	28.4 ± 3.4
% plants with largest nodule > 3 m	0.0	0.0	11.3 ± 1.6	2.9 ± 0.7
% chloride in topsoil (0–5 cm)	.004		.024	

Seedling growth was poor at Beerwah and seedling death occurred in all treatments (Table 1). The desmodium seedlings were pale green and some gradually died leaving a shrivelled, erect, dead seedling. Most surviving Beerwah plants had larger nodules than at Samford (Table 1). Dieldrin significantly increased the number of plants without nodules at Beerwah ($P < 0.001$) with a significant interaction between dieldrin and inoculum level ($P < 0.01$) in that plants without nodules were mainly limited to rows with dieldrin treated seed and without excess inoculum.

Seedling death at Beerwah was most severe from two to six weeks after emergence, but there was a second peak period of death after the rows were cut to ground level at eight weeks. Regrowth was usually good where there was little previous seedling death, but was poor where there was previously widespread seedling death. There was virtually no death of plants cut after eight weeks at Samford.

Growth at the two sites was so different that when seedling survival, yield and nodulation data for the 128 rows were subject to numerical classification using programmes MULTCLASS and GROUPER, the final fusion was between two groups of 64 comprising all the rows from Beerwah and all the rows from Samford.

The nitrogen concentration of eight week old plants at Samford was higher than at Beerwah (Table 2) despite poor nodule development at Samford (Table 1), suggesting that soil nitrogen levels at Samford were sufficient for desmodium growth. Plant copper, zinc, phosphorus, potassium, magnesium, sodium and sulphur concentrations were adequate but not excessive at both sites (Andrew, personal communication). Plant chloride levels at Beerwah were about ten times those at Samford (Table 2).

TABLE 2

Chemical composition, as % d.m., of eight weeks old D. intortum *seedlings at two sites—experiment* 1

	Samford		Beerwah	
	1st Sowing	*2nd Sowing*	*1st Sowing*	*2nd Sowing*
Nitrogen	3.88 ± .03	4.25 ± .07	2.21 ± .05	2.93 ± .19
Phosphorus	.29 ± .01	.22 ± .01	.32 ± .02	.20 ± .01
Chloride	.15 ± .01	.18 ± .05	1.54 ± .13	2.30 ± .26
Sodium	.02	.01	.03 ± .001	.04 ± .003

Experiment 2—Methods

Following the results from experiment one, where high plant chloride levels were associated with poor seedling growth at Beerwah, an experiment was laid out at Beerwah in spring 1970, on cleared virgin land adjacent to experiment one. The effect of potassium chloride and potassium sulphate on Greenleaf desmodium seedlings was examined at three levels of potassium. Two superphosphate rates were used following a suggestion that Greenleaf desmodium seedlings were susceptible to high phosphate levels in agar (Norris, 1971). The following treatments were applied in a factorial design:

(1) Form of potassium—KCl and K_2SO_4.
(2) Rate of potassium—25, 50 and 100 kg of K/ha.
(3) Rate of superphosphate—300 and 600 kg/ha.
(4) Time of sowing—two sowings, two weeks apart.

Lime at 600 kg/ha, copper sulphate at 8 kg/ha, zinc sulphate at 8 kg/ha and ammonium molybdate at 0.5 kg/ha were applied as a broadcast basal fertilizer and raked in before sowing. The experimental fertilizer treatments were applied to plots of $2\frac{1}{2} \times 1$ m and a 2 m row was sown to 400 viable Greenleaf desmodium seeds down the centre of each plot. The experiment was sited so that it was unlikely to receive chloride in subsurface seepage from adjacent sites and drains were placed around and within the experiment to minimise surface wash of fertilizer.

The experiment was a split-plot design with two replicates. Each block was split for times of sowing and the twelve fertilizer treatments arranged at random within each time of sowing. The following measurements were taken:

1. Seedling emergence and survival over an eight week period.
2. Initial row yield at eight weeks and at five regrowth harvests at eight week intervals, excluding winter.
3. Chemical analyses of top growth from the first harvest.

Experiment 2—Results

There was no significant treatment effect on seedling emergence, 66% of viable seed emerging in the first time of sowing and 70% in the second. There was a little seedling death on the potassium chloride plots so that the final seedling counts were 8% higher on the potassium sulphate plots ($P < 0.05$). In the first two harvests the desmodium yield with potassium chloride was approximately 85% of the yield with potassium sulphate ($P < 0.05$) but there was no effect of potassium fertilizer rate. In the third and fourth harvests there was no effect of fertilizer type but yields at the lowest potassium rate were only 85% of yields at the higher rates ($P < 0.05$). In plant material from the first harvest chloride levels never exceeded 1% and potassium levels never fell below 1.2%.

There was a highly significant doubling of yield at the higher superphosphate rate at each of five harvests. Row yields in the high phosphate treatments eight weeks after emergence were higher than measured at Samford over eight weeks in experiment 1.

Experiment 3—*Methods*

As there was no appreciable seedling death in experiment two, a further experiment on an adjacent site at Beerwah was sown to see if fineness of potassium chloride fertilizer, depth of sowing and depth of fertilizer incorporation had any effect on possible chloride toxicity.

The following treatments were applied as a factorial design:

(1) Sowing depth—0.5 and 2.0 cm.
(2) Depth of potassium fertilizer incorporation—2.5 and 7.5 cm.
(3) Fertilizer type—K_2SO_4, coarse KCl (> 2.0 mm), fine KCl (< 1.0 mm), applied at 100 kg K/ha.

Plot size, basal fertilizer (with 600 kg superphosphate/ha) and measurements taken were the same as for experiment 2. Treatments were not replicated but the trial was sown on three occasions during the 1970/71 summer.

Experiment 3—*Results*

Seedling emergence was not affected by any treatments. Seventy-two percent of viable seed emerged from both sowing depths, emergence being earlier from the shallower depth. There was marked seedling death in the potassium chloride treatments in sowings two and three (Table 3). There was a significant effect of potassium sulphate in improving seedling survival and row yield although there was no effect of depth of sowing or fertilizer incorporation (sowing times used as replicates). Consequently the statistical comparison of the effects of potassium sulphate and potassium chloride at each time of sowing (Table 3) was made using the students "t" test on measurements from four rows fertilized with potassium sulphate and from eight rows fertilized with potassium chloride. Plant chloride levels in rows fertilized with potassium chloride ranged from 0.6% (first sowing) to 2.8% (second sowing).

TABLE 3

Effect of fertilizer type on D. intortum *seedlings—experiment* 3

	% survival of emerged seedlings			row yield relative to sulphate row as 100		
	K_2SO_4	KCl	Significance	K_2SO_4	KCl	Significance
Sowing 1	98	94		100	83	
Sowing 2	83	53	*	100	46	†
Sowing 3	72	24	‡	100	27	‡

* significant to $P < 0.05$
† significant to $P < 0.01$
‡ significant to $P < .001$

DISCUSSION

The results presented have documented appreciable seedling death of *Desmodium intortum* at Beerwah. Such death was associated with the use of basal potassium chloride fertilizer. Varying superphosphate rates and use of soil sterilant did not affect seedling death and neither has the use of activated charcoal (unpublished data). Plant analyses suggested that no elements were deficient and that chloride was the only one likely to be toxic.

There is little possibility that high chloride levels measured in plants came from either natural soil chloride or from desmodium seed. Chloride in the topsoil adjacent to the experimental sites at Beerwah was consistently less than 0.01%, typical values for this soil (Andrew and Bryan 1955). The seed used for these experiments contained 0.12% chloride.

In the initial Beerwah experiment, which led to this investigation, seedling death of Greenleaf desmodium but not of Siratro or setaria followed the usual basal fertilizer application (Bryan 1968) of 137 kg potassium chloride/ha. No chloride analyses were made of affected seedlings in this trial but analyses have since been made on greenleaf desmodium from two other field sowings given this basal dressing. In both cases some seedling death was noted and chloride levels of surviving four week old seedlings ranged from 1.1 to 3.5%.

Seedling growth of desmodium was very good at Samford in the first experiment in this series whereas emergence and growth at Beerwah were poorer with appreciable seedling death. Some seeds in the Beerwah sowing had germinated but failed to emerge. Seedling death was associated with high chloride levels in surviving seedlings. The poorer growth of surviving plants at Beerwah as compared with Samford could be expected with the high chloride levels in Beerwah plants (Hall, 1971). Many of these surviving plants died after they were cut back at eight weeks and this was presumably associated with marginal chloride toxicity, this effect being noted in water culture by Hutton (1971). Although this trial only received 135 kg of potassium chloride/ha, top soil sampling for chloride suggested that extra chloride may have accumulated on the Beerwah experiment from an adjacent upslope area which had been recently fertilized with potassium chloride.

In the second experiment there was very little harmful effect of potassium chloride compared with potassium sulphate whereas this was very marked in two of the three sowings in the third experiment. A more injurious effect of chloride ions than equivalent concentrations of sulphate ions has been observed in many studies (Eaton, Olmstead and Taylor, 1971).

Consequently the available data suggests that broadcast basal potassium chloride fertilizer, applied within an approximate range of from 100 to 200 kg/ha, can at times cause seedling death of Greenleaf desmodium seedlings. The dangers associated with intimate contact of seed and fertilizer are well known (Stonebridge and Mackie 1969) but it is unusual to have toxicity problems associated with broadcast fertilizers at a rate such as used for potassium chloride in these experiments. Relative to most tropical legumes, the death of *D. intortum* seedlings due to potassium chloride application is in keeping with the high sensitivity to chloride of this species shown in glasshouse studies (Andrew 1971, Andrew and Robins 1969, Hutton 1971). The poor buffering capacity of the loamy sand topsoil at Beerwah compared with the clay loam topsoil at Samford would also intensify chloride toxicity problems.

Combining data from all experiments, chloride levels of below 1% in surviving eight week old plants were rarely associated with previous seedling death, levels between 1% and 2% had a variable effect and levels above 2% were usually associated with seedling death and poor growth of surviving plants. As there was a consistent relationship between chloride uptake per gm d.m. and death of desmodium seedlings, the inconsistent results between experiments follow from an inconsistent relationship between chloride application and chloride uptake per gm d.m.

Seedling death was greatest when seed and fertilizer were applied into wet soil and seedlings grew under cloudy and wet conditions, presumable with limiting light and temperature. The resultant depression in growth rate may have increased chloride uptake per gm d.m. (Hall 1971). There was a negative linear relationship between seedling survival and rainfall in the four weeks prior to sowing and fertilizing ($r = -0.88$), based on the mean survival percentage from plots fertilized with potassium chloride for each of the seven times of sowing studied in the three experiments. This is the opposite result to that which would be expected if chloride toxicity was due to natural soil salinity. In the latter case heavy rain prior to sowing would leach salt through the soil profile and thus presumably enhance seedling survival.

Possible ways of avoiding chloride toxicity of seedling desmodium in field sowings include either using potassium sulphate or a lower rate of potassium chloride during establishment. The results from experiment two suggest that at Beerwah the initial potassium chloride application can be lowered without risk of potassium deficiency at establishment. A delay between fertilizing and sowing could also reduce chloride toxicity but the effectiveness of delay would depend on soil moisture and chloride movement.

A common practice in preliminary pasture species screening trials, where fertilizer requirements are often inadequately known, is to use heavier basal fertilizer dressing than may be actually required (Bryan *et al.* 1964). Care may be needed with potassium chloride in such situations where chloride sensitive species such as Greenleaf and Silverleaf desmodium (Andrew 1971) are being sown. The danger would be more acute in areas such as the Queensland wallum where soils are poorly buffered and seedling growth will often occur under wet and overcast conditions with limiting temperature and light intensity.

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